

# Correlation of CN/C<sub>2</sub> ratios to of ultrananocrystalline diamond (UNCD) film properties in Microwave plasmas

## Scientific Achievement

A detailed study of CN/C<sub>2</sub> ratios as a function of nitrogen content has been undertaken in our laboratory using Optical Emission Spectroscopy (OES) on the plasma phase in a conventional MW CH<sub>4</sub>-Ar-rich gas mixture successfully used for UNCD film deposition.

The principal features observed in OES are due to C<sub>2</sub> and CN molecules arising from reactions between acetylene and N<sub>2</sub>. The addition of nitrogen to the plasma activity enhances the CN emission. In the Ar-CH<sub>4</sub>-N<sub>2</sub> plasma the chemical processes lead to a shift in the C<sub>x</sub>H<sub>y</sub> species towards CN-containing species.

The investigation of these results led to the development of a simple thermo-chemical model, able to explain the observed experimental trends. The agreement between simulated and experimental data points to a simple and powerful method for monitoring plasma processes that would be difficult if not impossible to follow otherwise.

For the first time a strong correlation has been observed between the OES results and the film properties. The CN/C<sub>2</sub> ratio and the n-type film conductivity are linked by the following relationship:

$$\text{Log } (K \cdot \text{Conductivity}) \approx \text{CN/C}_2.$$

## Significance

UNCD thin films consist of 2-5 nm grains of pure sp<sup>3</sup>-bonded carbon and 0.5 nm wide grain boundaries (GB), consisting of sp<sup>2</sup>, sp<sup>2+x</sup> and sp<sup>3</sup> bonded carbon. Such films have interesting properties closely connected to their unique nanoscale morphology and electronic structure.

The addition of nitrogen to the CH<sub>4</sub>/Ar synthesis gas has a profound impact on UNCD film electrical conductivity leading to the **highest known ambient temperature n-type conductivity of any diamond thin film** up to several hundreds Ω/cm at ambient temperatures.

The relationship:  $\text{Log } (K \cdot \text{Conductivity}) \approx \text{CN/C}_2$  established by this work is important since it will enable one to produce film of any desired conductivity simply by experimentally adjusting the CN/C<sub>2</sub> ratio in the plasma.

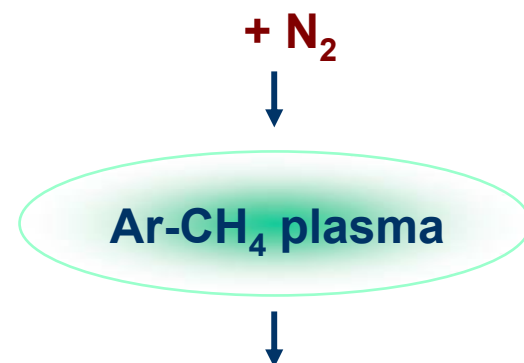
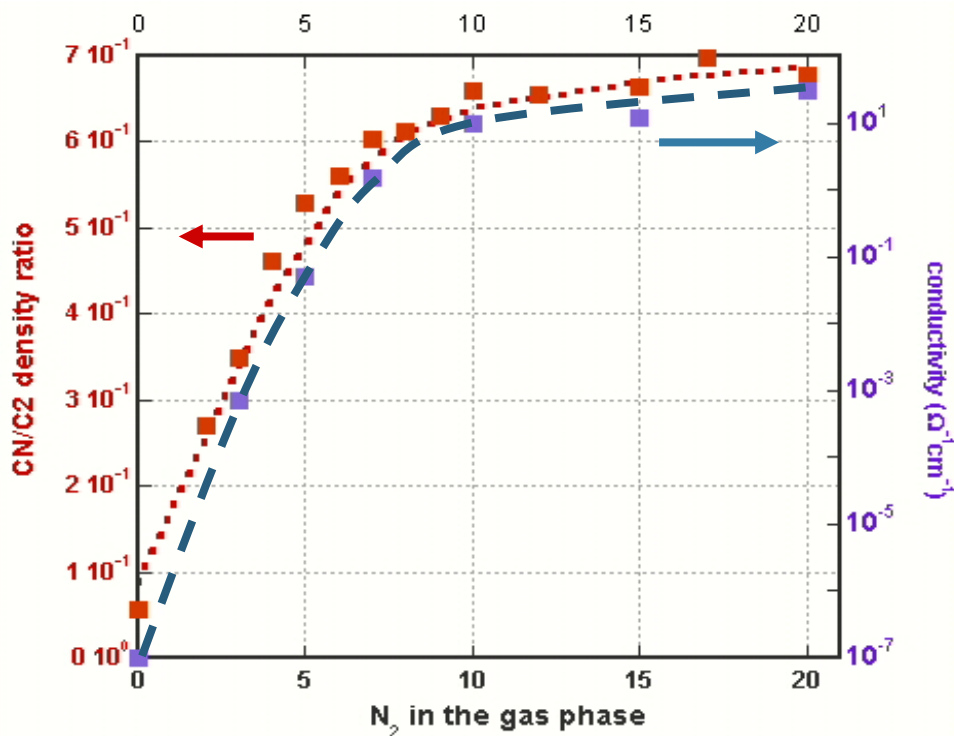
The next step will be attempts at the development of a coherent theory of conductivity, which can rationalize all the features of electron transport in n-type UNCD films that have been observed up to now.

This work has been presented as an invited talk at the AIChE 2005 Annual Meeting held in Cincinnati (OH) on the 31<sup>st</sup> October-4 November 2005.

## Performers

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# Correlation of CN/C<sub>2</sub> ratios to ultrananocrystalline diamond film (UNCD) properties in Microwave plasmas



UNCD with the **highest known ambient temperature *n*-type conductivity** of any diamond thin film.

$$\text{Log}(K \cdot \text{Conductivity}) \approx \text{CN/C}_2$$

For the first time a very strong correlation has been observed between the Optical Emission Spectroscopy (OES) results on the plasma used for UNCD deposition and the film electrical properties itself.